Piezo · Nano · Positioning

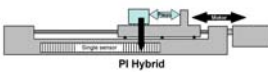
MP84E User Manual

M-511.HD Ultra-High-Resolution Positioner

Release: 1.0.0 Date: 2008-02-27

This document describes the following product:

- M-511.HD
  Ultra-High-Resolution Positioning Stage with Hybrid Drive



Auf der Römerstr. 1 · 76228 Karlsruhe, Germany
Tel. +49-721-4846-0 · Fax: +49-721-4846-299
info@pi.ws · www.pi.ws

Declaration of Conformity

according to ISO / IEC Guide 22 and EN 45014

Manufacturer:	**Physik Instrumente (PI) GmbH & Co. KG**	CE
Manufacturer´s Address:	Auf der Römerstrasse 1 D-76228 Karlsruhe, Germany	

The manufacturer hereby declares that the product

Product Name: **Ultra-High-Resolution Positioning Stage with Hybrid Drive**
Model Numbers: **M-511.HD**
Product Options: **all**

complies with the following European directives:
73/23/EWG, Niederspannungsrichtlinie / 73/23/EEC, Low voltage directive
89/336/EWG, EMV- Richtlinie / 89/336/EEC, EMC-Directive
98/37/EG, Maschinenrichtlinie / 98/37/EC, Machinery Directive

The applied standards certifying the conformity are listed below.

Electromagnetic Emission: EN 61000-6-3, EN 55011

Electromagnetic Immunity: EN 61000-6-1

Safety (Low Voltage Directive) : EN 61010-1

Safety of Machinery: EN 12100

February 20, 2007
Karlsruhe, Germany

Dr. Karl Spanner
President

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M-511HD_User_MP84E100.doc

About This Document

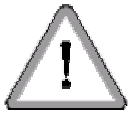
Users of This Manual

This manual is designed to help the reader to install and operate M-511.HD Ultra-High-Resolution Positioning Stage with Hybrid Drive. It assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts and applicable safety procedures.
The manual describes the physical specifications and dimensions of the M-511.HD Linear Positioning Stages as well as the motion control parameter settings which are required to put the associated motion system into operation.
This document is available as a PDF file. For updated releases visit the download area on www.pi.ws, contact your Physik Instrumente Sales Engineer or write info@pi.ws

Conventions

The notes and symbols used in this manual have the following meanings:

WARNING



Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in injury or death.

CAUTION

!

Calls attention to a procedure, practice, or condition which, if not correctly performed or adhered to, could result in damage to equipment.

NOTE

Provides additional information or application hints.

Related Documents

The motion controller and the software tools which might be delivered with M-511.HD Linear Positioning Stages, are described in their own manuals. Updated releases are available for download from www.pi.ws or email: contact your Physik Instrumente Sales Engineer or write info@pi.ws.

Contents

1 Introduction

1.1 M-511.HD Description

M-511.HD Ultra-High-Resolution Positioners are equipped with a combination drive consisting of a motorized and a piezo actuator, which provides minimum incremental motion of 4 nm. High-resolution incremental scales and appropriate interpolation electronics achieve a design resolution of 2 nm. Reference and limit switches are integrated for easy handling and protection of the equipment. The M-511.HD can be controlled by the C-702 Hybrid controller.

The M-511.HD features can be summarized as follows:

- 100 mm Travel Range with 2 nm Actual Resolution
- Speeds up to 125 mm/s
- Load Capacity to 50 kg
- Millisecond Settling to Nanometer Accuracy
- High Velocity Constancy
- Active Compensation of Stick/Slip Effects While Starting
- Active Compensation of Backlash
- Reliable Execution of Minimal Increments
- High Drive and Holding Forces at Minimal Power Consumption and Heat Generation

Hybrid systems are ideal for applications where the position of an incident needs to be read and to be repositioned precisely, or where an external target position needs to be hit within few a nanometers, such as in surface inspection or metrology.

Fig. 1 M-511.HD with C-702 controller

1.2 Hybrid Technology

PI's hybrid technology stages are driven by both a flexure-guided piezo actuator and DC motor at the same time. Because a single, extremely high-resolution incremental sensor (placed close to the moving platform) is used for the servo-loops of both drives, nanometer-realm trajectory resolution is attained over the entire 100 mm travel range.

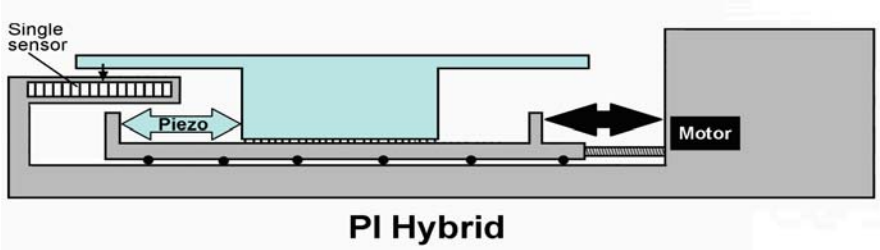


Fig. 2. Hybrid system schematic representation: The incremental sensor sees the position of the platform, which is driven by both the piezo and the motor at the same time

During operation, the piezo actuator with a travel range of a few microns is continuously working to smooth out the motion irregularities of the motor. This is made possible by the controller, which calculates the desired trajectory and controls the motion with two separate servo loops running at different rates but using data from the same sensor.

Precision recirculating ball bearings assure straightness of travel of better than 1 µm / 100 mm. The stage base is precision machined from high-density, stress relieved aluminum for exceptional stability and minimum weight.

Low-voltage PZTs (±36 V) and flexures are employed in the piezo drive section. The flexures provide zero-backlash motion and excellent guiding accuracy.

1.3 Prescribed Use

Based on their design and realization, M-511.HD Ultra-High-Resolution Positioners must not be used for applications other than stated in this manual.

Observe the safety precautions given in this User Manual. Operation other than instructed in this Manual may affect the safeguards provided.

M-511.HDs conform to Measurement Category I (CAT I) and may not be used for Measurement Categories II, III or IV. Other use of the device (i.e. operation other than instructed in this Manual) may affect the safeguards provided.

M-511.HDsmeet the specifications of EN 61010 for safe operation and are designed to operate under normal ambient conditions at least as listed here. More stringent conditions given in the Specifications table (p. 15) are, of course, also met.

- Indoor use
- Altitude up to 2000 m
- Temperature range 5°C to 40°C
- Max. relative humidity 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C
- Line voltage fluctuations not greater than ±10% of the line voltage
- Transient overvoltages as typical for public power supply
  Note: The nominal level of the transient overvoltage is the standing surge voltage according to the overvoltage category II (IEC 60364-4-443).
- Degree of pollution: 2

1.4 Safety Precautions

WARNING—Crush Hazard

To avoid damage or injury, do not put anything where the moving platform or any connected object could possibly trap it.

CAUTION—Unexpected Motion

When the stage is first connected to the motor controller, be aware that the stage could start an undesired move.

CAUTION—Avoid Damage

Disassembly will result in loss of the specified accuracy as well as voiding the warranty. A PZT system achieves its high accuracy by the proper matching of the mechanics and the drive.

Do not exceed the maximum push or pull forces given in the technical specifications. Doing so can result in damage to the PZT elements or misadjustment of the mechanics.

Do not drop the stage or subject it to any kind of mechanical shock. Doing so can result in damage to the PZT elements or misadjustment of the mechanics.

Attach the positioning stage only at the mounting holes provided for that purpose. Attach loads only at the threaded holes provided for that purpose. Follow the mounting instructions provided.

Overlength mounting screws may damage the stage. Be sure to respect the specifications on the dimensional drawing on p. 19.

Do not exceed the push/pull load capacity (in the motion direction); it is limited to 80 N (18 lbf).

1.5 Unpacking

Unpack the M-511.HD Linear Translation Stage with care. Compare the contents against the items covered by the contract and against the packing list.
The following components are included:

- Stage

- M-500.PS power supply and power cord
- K040B0055 motor cable (3 m) for connecting the stage to the controller
- Screw set with four M6x30, four M4x30 and four M4x16 metric screws together with 2 Allen wrenches.
- User Manual (this document, MP84E)

Inspect the contents for signs of damage. If parts are missing or you notice signs of damage, please contact PI immediately.
Save all packing materials in case the product need be shipped again.

Standard and custom adapter plates may be available for interfacing M-511.HD stages with your application. Contact your PI Sales Engineer or write info@pi.ws if you need additional information.

2 Start-Up

2.1 Mechanical Mounting

2.1.1 Operating Environment

M-511.HD series stages should be operated in clean environments. Although the bearings and ballscrew are covered to offer some protection against dust and liquids, the case is not hermetically sealed. Make sure that metal dust and liquid spray do not enter the case via the gap between the cover and the aluminum body.

2.1.2 Mounting

Be sure not to exceed load limits during or after mounting. Standard M-511.HD series stages can be mounted horizontally or vertically. If subjected to normal gravitational loading when mounted vertically, the motor housing must be at the top end.

To achieve the specified guiding accuracy, the stages have to be mounted on a surface flat enough to avoid torsion of the basic profile.

NOTE

If the counter-sunk mounting holes in the stage base are covered by the platform, you must first move the platform to a position which allows access. Read "Moving the Stage (p. 8)" for instructions.

To mount an M-511.HD stage on a base plane, use the two holes for M6 screws or the four counter-sunk holes for M4 screws in the stage base and the corresponding mounting screws which come with the stage. The arrangement of the M6 holes complies with the 25 mm-hole pattern of standard metric honeycomb tables.
You have best access to the M6 mounting holes when the platform is at its central reference switch (for reaching the reference position see the controller User Manual).

2.2 Moving the Stage

WARNING—Crush Hazard

Never put anything where the moving platform or any connected object could possibly trap it! The moving platform can accelerate rapidly and generate high forces which can cause damage or injury.

CAUTION

Do not exceed the push/pull load capacity (in the motion direction); it is limited to 80 N (18 lbf).

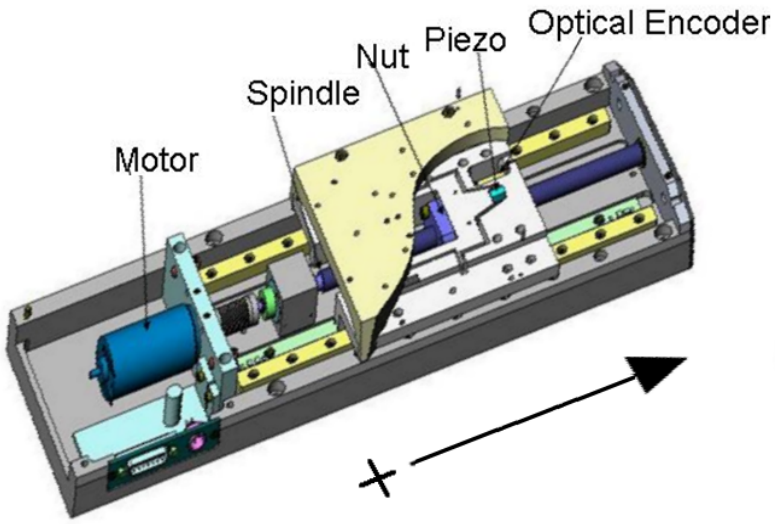


Fig. 3: M-511.HD stage unit, arrow indicates positive motion direction

Prior to operation read the controller documentation.

To operate a stage, proceed as follows:

1. Install/connect the controller following the instructions in the controller manual. If you are going to use a host computer, install the host software in the host computer. This procedure is described in the controller User Manual and/or associated software manuals.

2. Connect the stage to the controller using the connecting cable which comes with the stage (part number K040B0055). With multi-axis systems, be sure to note the axis designation of the connection selected.

3. Connect the stage to the M-500.PS power supply, which also comes with the stage, and connect the power supply to line power (wide range input). To turn on the M-500.PS power supply, place the "-/o"-rocker switch in the "-" position

4. Command a few test moves to make sure everything is working properly

3 Operational Considerations

3.1 Limit Switches

M-511.HD stages are protected against running into the hard stop by magnetic limit sensors (Hall-effect sensors with TTL drivers) at each end of travel.

The limit switches act to inhibit commanded motion as appropriate. The limit signals, TLL active high, are available on the controller connector.

CAUTION !

Crashes can cause irreparable damage. Test limit switch operation at low speeds. Stop system if necessary. Do not let it run against a hard stop.

3.2 Position Reference Signal Sensors

A position reference sensor is located approximately in the middle of the operating range and can be used to determine the absolute position of the stage within 1 µm accuracy. Always approach the reference sensor from the same side to reach the same position. The difference in the reference points when approached from the positive side and from the negative side is about 0.2 mm to 0.4 mm.

The reference sensor in M-511.HD stages provides a static signal level which depends on the platform position. If the platform is on the "positive side" of the reference switch, the signal is +5 V, while if the platform is on the "negative side", the signal level is 0 V (see Fig. 3).

3.3 Linear Scale Position Encoder

An optical linear encoder is mounted in the M-511.HD series stages. It measures relative motion with 0.002 µm linear resolution and can be used at velocities up to 125 mm/s.

The optical encoder is mounted in the center of the stage, close to the platform for highest accuracy. The linear encoder measures the position of the moving carriage directly, thus eliminating drive train errors such as non-linearity, backlash or elastic deformations.

The encoder is based on an optical grating and a noncontacting read head with integrated signal conditioner and interpolator.

3.4 Controller

M-511.HD series stages can be used with the C-702 Hybrid Drive controller.

Servo-control of the stage relies on separate, coupled control loops for the piezo and motor drives both using the single high-resolution position feedback sensor (parallel metrology). This makes the high resolution available over the entire travel range.

Both the piezo and motor servo-control loops are active at the same time, meaning that the trajectory deviation is also kept in the nanometer range during motion. Furthermore, the piezo position is fed back through an integrator into the motor control loop, so that the motor will tend to drive the piezo voltage toward zero when settling, thus preserving piezo lifetime.

Fig. 4: C-702 Hybrid drive controller

4 Troubleshooting

4.1 Diagnosis

Positioner does not move.

Cables not connected properly:
- Check K040B0055 connecting cable.

Check power supply:
- Verify that the included MS-500.PS power supply is connected and turned on.

Positioner or positioner cable is defective:
- Test system with a working cable and/or positioner of the same type to determine if the fault is in the positioner, cable or elsewhere (positioners of a different type may malfunction due to unsuitable parameter settings on the controller).

Wrong command or wrong syntax:
- Check the error code (use the ERR? command to read the error code; see controller and software manuals for the error code explanations).

Positioner is not referenced:
- The controller will not execute closed-loop motion commands as long as the positioner is not referenced—(ERR? replies "5", see controller and software manuals). Reference the axis as described in controller user manual.

Wrong axis commanded:
- Check if commanded axis is that of the desired positioner.

Incorrect configuration:
- Check the parameter settings on the controller (SPA?, see controller and software manuals for details).

Positioner does not reach position with expected accuracy.

Motion parameters are not optimized:
- Adjust the motion parameters according to the values provided by PI

Positioner runs jerkily and not smoothly enough.

Motion parameters are not optimized:
- Adjust the motion parameters according to the values provided by PI.

Positioner did not stop in time and ran into a hard stop.

The limit switches did not stop the positioner in time:

- Too high velocity. See "Limit Switches" section.
- Turn off the motor.

4.2 Customer Service

If problems persist, call your local PI representative or write to info@pi.ws; please have the following information about your system ready:

- Product codes and serial numbers of all products in the system
- Current firmware version of the controller
- Software version of driver or host software
- Operating system on host PC

4.3 Disposal

In accordance with EU directive 2002 / 96 / EC (WEEE), as of 13 August 2005, electrical and electronic equipment may not be disposed of in the member states of the EU mixed with other wastes.

To meet the manufacturer's product responsibility with regard to this product, Physik Instrumente (PI) GmbH & Co. KG will ensure environmentally correct disposal of old PI equipment that was first put into circulation after 13 August 2005, free of charge.

If you have such old equipment from PI, you can send it to the following address postage-free:

Physik Instrumente (PI) GmbH & Co. KG
Auf der Römerstr. 1
76228 Karlsruhe, Germany

5 Technical Data

5.1 Specifications

Models	M-511.HD	Units
Active axes	X	
Motion and positioning		
Travel range	100	mm
Integrated sensor	Linear Encoder	
Sensor resolution	0.002	µm
Design resolution	0.002	µm
Min. incremental motion	0.004	µm
Hysteresis at the platform	0.01	µm
Unidirectional repeatability	0.01	µm
Accuracy	<0.05	µm
Pitch	±25	µrad
Yaw	±25	µrad
Straightness	1	µm
Flatness	1	µm
Max. velocity	125	mm/s
Origin repeatability	1	µm
Mechanical properties		
Drive screw	Recirculating ballscrews	
Guiding	Precision linear guiding rails, recirculating ball bearings	
Spindle pitch	2	mm/rev.
Load**	500	N
Push-/pull force	80/80	N
Lateral force	200	N
Drive properties		
Drive type	Hybrid: piezo actuator riding on motor-leadscrew-drive	
Motor type	DC motor	
Operating voltage (motor)	24	V
Electrical power	30	W
Piezo drive type	PICMA® Multilayer piezo with flexure	

Piezo voltage	±36	V
Limit and reference switches	Hall-effect	
Miscellaneous		
Operating temperature range	-20 to +65	°C
Material	Al (black anodized)	
Mass	5.1	kg

5.2 Performance

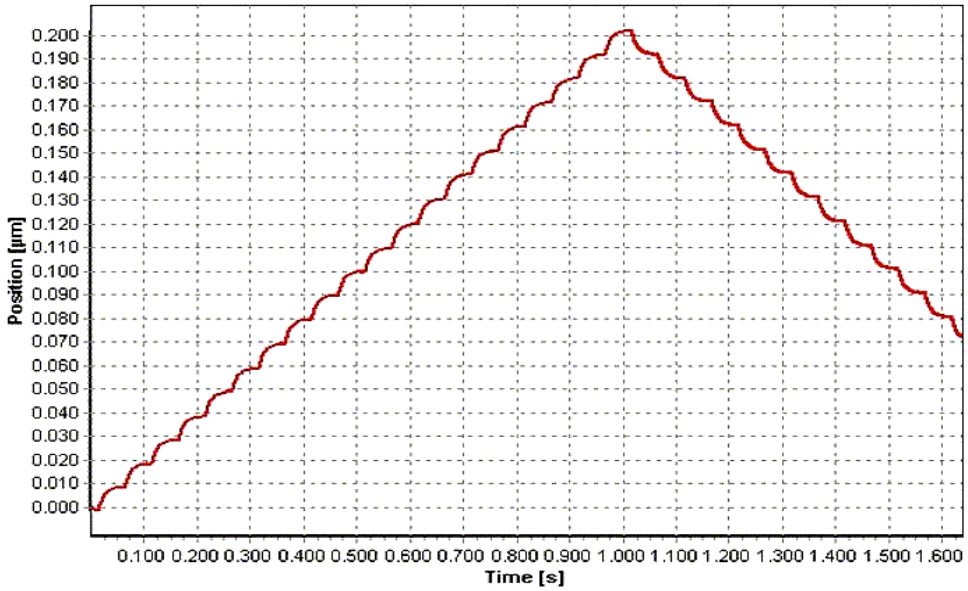


Fig. 5: Step response of the hybrid stage for 10 nm steps, measured with external laser interferometer

Fig. 5 shows the step performance with a series of 10 nm steps forward and backward. The motion was measured with an external interferometer. The hysteresis measured is considerably less than 1 nm.
During motor motion the piezo actuator compensates for the influences of friction and roughness, as shown in Fig. 6.

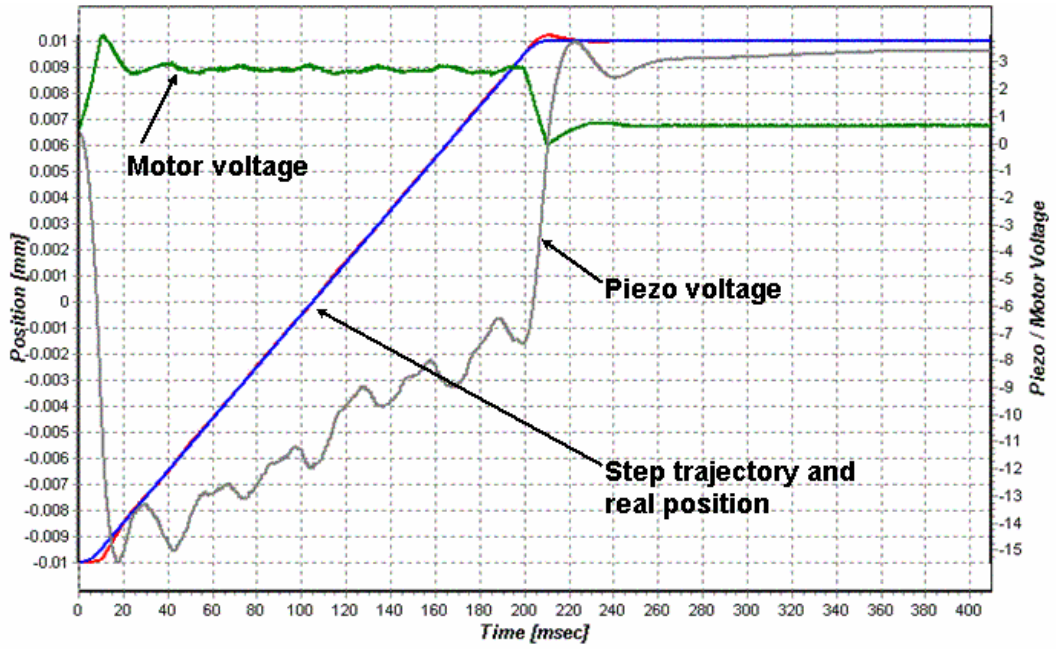


Fig. 6: Motor voltage (velocity) and piezo voltage (position correction) during 20 µm step

5.3 Dimensions

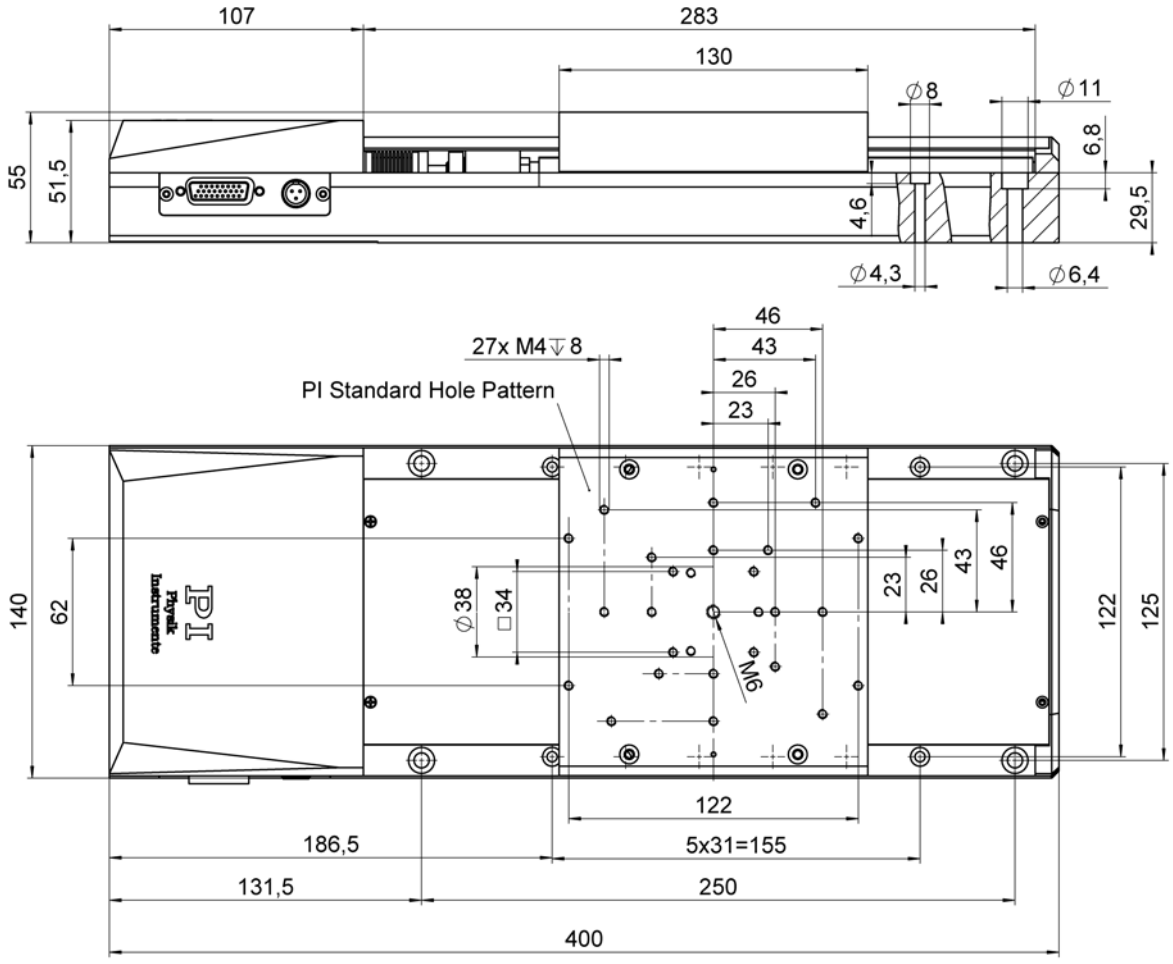


Fig. 7 M-511.HD dimensions in mm, decimal places separated by commas in drawings

5.4 Pin Assignments

5.4.1 Controller Connector

The pin numbers and associated signal names of the sub-D 26-pin "Controller" socket are as follows:

	10 VCC	
1 GND		19 GND
	11 VCC Piezo	
2 pos. SDI A/ ENC A*		20 GND
	12 VCC Piezo	
3 neg. SDI A/ ENC A*		21 BRAKE
	13 REF	
4 pos. ENC B*		22 Analog GND
	14 pos. END	
5 neg. ENC B*		23 DAC
	15 neg. END	
6 pos. SCLK		24 Spindle REF
	16 DOW A	
7 neg. SCLK		25 pos. SDO
	17 PWM MAG	
8 pos. SEN		26 neg. SDO
	18 PWM SIGN	
9 neg. SEN		

* These signals are not used for servo control but provided for diagnostic purposes.

5.4.2 Power Connector

Type: 3-pin, round socket (Switchcraft Tini Q-G)

Pin	Function
1	GND (power)
2	Voltage input (+24 V ±3 V)
3	n.c.

Fig. 8 Power connector, front view